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Approach to Developing Predictive Capability for Hohlraum Drive and Symmetry

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Approach to developing predictive capability for hohlraum drive and symmetry*

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Summary

Currently, we do not have the ability to predict the hohlraum drive and symmetry without requiring *ad hoc* adjustments to physics models. This document describes a plan for code improvements and focused physics validation experiments:

- Integrated experiments identify areas for improvement in existing models
- Incremental improvements and new physics packages are applied to the radiation hydrodynamics codes as developed and needed
- Focused physics experiments isolate specific effects for model validation

Efforts proceed in parallel with frequent reassessment of predictive capability.

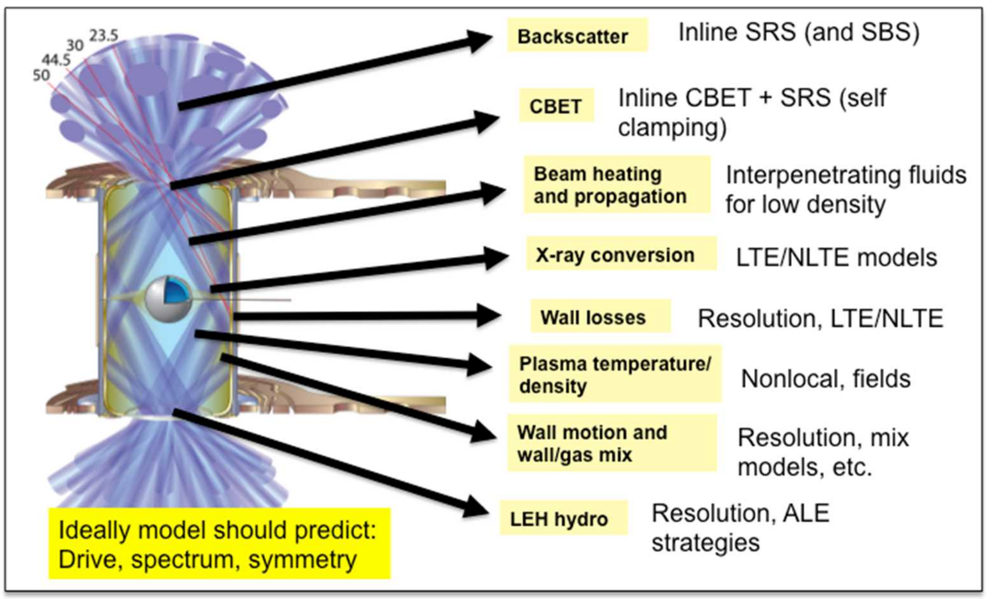

Fig. 1: Physical processes governing x-ray drive and symmetry and areas for model improvement

Predicting radiation drive and symmetry requires simulating the brightness, spectrum, and location of the laser-heated spots on the hohlraum wall.

The re-emission (albedo) of the wall must also be predicted. Several processes must be included in an integrated numerical model (Fig. 1). The lasers enter through laser entrance holes (LEH), where cross beam energy transfer (CBET) occurs. The beams refract and are absorbed via inverse *bremsstrahlung*. Laser plasma instabilities (LPI) can reflect light out of the hohlraum or transfer energy to fast electrons. Laser light is absorbed in the high-Z wall, forming hot coronal plasma. Heat is transported from the corona to the denser x-ray conversion layer, where the heat is converted efficiently to

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x rays. The x rays fill the hohlraum, driving a radiative ablation (Marshak) wave into the wall. The ablated wall expands and collides with capsule ablator plasma or fill-gas plasma. This interface is typically Rayleigh-Taylor unstable.

Integrated measurements of x rays escaping the hohlraum and implosion symmetry identify areas for improvement in existing models.

These experiments are described in Table I. The initial goal is to develop a predictive model in the absence of large amounts of backscatter and CBET. These processes are very difficult to predict. This leads us to study near-vacuum and low gas fill (0.03-0.6 mg/cm^3) hohlraums that are currently being used for high density carbon (HDC) implosions. The goal is to identify discrepancies between the calculations and the measurements. Hypotheses that account for the differences are tested using alternative models.

Description	Motivation	Observables
Hohlraum density scan	Find limits of LPI and energetics	Backscatter, x-ray flux, symmetry capsule bang time
Case-to-capsule variation	Find limits of hohlraum filling	Backscatter, x-ray flux, symmetry capsule bang time
Foam ball	Measure early-time symmetry	Backlit imaging of foam ball
Re-emit ball	Measure picket symmetry	re-emission of high-Z ball
VISAR trough	Measure early-time symmetry	Shock velocity symmetry

Table I. Integrated hohlraum experiments in low gas fill (0.03-0.6 mg/cm^3) hohlraums.

Several improvements to the current hohlraum model are under development.

The standard model for hohlraum simulations (the High Flux Model) was developed after the Hohlraum Energetics experiments of 2009 [1]. The inline non-LTE model (DCA) uses highly averaged atomic models with limited coverage of highly excited configurations. Higher fidelity non-LTE atomic physics models are too expensive to run inline. Two efforts are underway to remedy this:

1. Extend current models through targeted simulations to identify the highest leverage enhancements
2. Research methods to use tabulated non-LTE opacity, emissivity, and equation of state information in place of inline calculations

Improvements to the transition from non-LTE models to LTE tabular opacities are also being developed. Thermal transport models beyond a static flux limiter are being tested. These include dynamic flux limiters, non-local thermal electron conduction, and magnetohydrodynamics (MHD). Self-consistent inline models for CBET and backscatter are also being tested. These models can be validated by spatially and temporally resolved measurements of hohlraum plasma conditions.

Focused physics experiments attempt to isolate specific effects.

Each physics experiment helps validate one or more physics packages in the codes. (Table II). Some experimental techniques have already been developed, such as the dot spectroscopy technique and the quartraum. Others have been tested at OMEGA or ORION and can be developed further on the NIF .

The efforts described here proceed in parallel with frequent reassessment of predictive capability.

Measured quantity	Experimental method	Physical models
plasma temperature and flow	microdot spectroscopy	heat transport (non-local, magnetohydrodynamics)
coronal temperature	L-shell spectroscopy	heat transport, non-LTE atomic physics
highly resolved x-ray spectroscopy	x-ray spectroscopy (VIRGIL)	non-LTE atomic physics
non-LTE emission	x-ray spectroscopy, x-ray imaging	non-LTE atomic physics
wall motion and wall/gas mix	backlit radiography, microdot imaging	hydrodynamic stability, multi-fluid or kinetic effects
cross-beam energy transfer	laser-spot imaging (quartraum)	inline LPI models
interpenetrating plasmas	Thomson scattering of colliding plasmas (OMEGA)	multi-fluid or kinetic models

Table II. Focused physics experiments for radiation hydrodynamic model validation

References

1. M. Rosen, H. Scott, D. Hinkel, E. Williams, D. Callahan, R. Town, L. Divol, P. Michel, W. Kruer, L. Suter, R. London, J. Harte, and G. Zimmerman, “The Role of a Detailed Configuration Accounting (DCA) Atomic Physics Package in Explaining the Energy Balance in Ignition Scale Hohlraums” High Energy Density Phys. 7, 180 (2011).